

titanate powder, sintering to a closed-pore porous body, followed by hot-isostatic pressing to a void-free body. The components are configured into a multilayer array with the use of a solder-bump technique as the enabling technology so as to provide a parallel configuration of components that has the capability to store electrical energy in the range of 52 kWh. The total weight of an EESU with this range of electrical energy storage is about 336 pounds.--

At page 8, beginning of line 8, change the following:

-- Brief Description of the Drawings--

In the Claims

Please amend claims 1-16 as follows.

1. (Amended) An electrical-energy-storage unit comprising of components fabricated by the method steps as follow;
 - o Wet-chemical-prepared calcined composition-modified barium titanate powder composed of oxide constituents of barium (Ba), calcium (Ca), titanium (Ti), zirconium (Zr), manganese (Mn), yttrium (Y), and neodymium (Nd) forming a single-phase solid solution, with a relativity permittivity of 33,500; and
 - o a first uniform coating of 100 Å of aluminum oxide resulting in a single-coated calcined composition-modified barium titanate powder; and
 - o a second uniform coating of 100 Å of calcium magnesium aluminosilicate glass resulting in a double-coated calcined composition-modified barium titanate powder that has a relative permitivity of 29,480; and

- blending this double-coated composition-modified barium titanate powder with an organic resin binder to provide a suitable rheology for screen printing; and
- screen-printed into interleaved multilayers of alternating offset nickel electrode layers 12 and double-coated calcined composition-modified barium titanate high-relative-permittivity layers 11 with the use of screening inks having the proper rheology for each of the layers; and
- dry and cut the screen-printed multilayer components 15 into a specified rectangular area; and
- sinter the screen-printed multilayer components 15 to closed-pore porous ceramic bodies; and
- hot isostatically press the closed-pore porous ceramic bodies into a void-free condition; and
- grind and polish each side of the component to expose the alternating offset interleaved nickel electrodes 12; and
- nickel side bars 14 are connected to each side of the components 15 that have the interleaved and alternating offset nickel electrodes 12 exposed by applying nickel ink with the proper rheology to each side and clamping the combinations together; and
- components and side nickel bar combination 14-15 are then heated at the proper temperature and time duration to bond them together; and
- wave solder each side of the conducting bars; and

- components 15 with the connected nickel side bars 14 are then assembled into the first array, utilizing unique tooling and solder-bump technology; and
 - the first arrays are then assembled into the second array; and
 - the second arrays are then assembled into the EESU final assembly.
2. (Amended) An electrical-energy-storage unit as recited in Claim 1 that did not degrade due to being fully charged or discharged because of the second coating of glass onto the double-coated composition-modified barium titanate powder being nonreactive with the nickel electrodes in contact with the glass at applied voltages up to the working voltage of 3500 V, from the lower to the upper temperature limits of a commercial product.
 3. An electrical-energy-storage unit as recited in Claim 1 that was rapidly charged to a working voltage of 3500 V and completely discharged repeatedly and rapidly without incurring any damage or any long-term degradation of the specification to the components because of the electrically parallel configuration of the dielectric layers within a component, of the components, and also of the arrays of components, which resulted in a very-low-resistance conductive paths.
 4. (Amended) An electrical-energy-storage unit as recited in Claim 1 that due to the unique double coating of the composition-modified barium titanate powder and the hot isostatic pressing at the near-minimum-temperature viscous-flow condition of the glass, 800° C, a dielectric voltage breakdown strength of 6.35×10^6 V/cm was achieved across the terminals of the components.

5. (Amended) An electrical-energy-storage unit as recited in Claim 1 that had an ease of manufacturing due to the softening temperature of the calcium magnesium aluminosilicate glass allowing the relatively low sintering and hot-isostatic-pressing temperatures of 800° C which in turn provided a void-free ceramic body.
6. (Amended) An electrical-energy-storage unit as recited in Claim 1 that had an ease of fabrication due to the softening temperature of the calcium magnesium aluminosilicate glass allowing the relatively low sintering and hot-isostatic-pressing temperatures of 800° C which in turn allow the use of nickel for the conduction-path electrodes.
7. (Amended) An electrical-energy-storage unit as recited in Claim 1 that had an ease of fabrication due to the softening temperature of the calcium magnesium aluminosilicate glass allowing the relatively low sintering and hot-isostatic-pressing temperatures of 800° C, which feature along with the coating method provided a uniform-thickness shell of the calcium magnesium aluminosilicate glass and in turn provides hot-isostatic-pressed double-coated composition-modified barium titanate high-relative-permittivity layers that were uniform and homogeneous in microstructure.
8. (Amended) An electrical-energy-storage unit as recited in Claim 1 that due to the double coating of the basis particles of the composition-modified barium titanate powder reduced the leakage and aging of this material by an order of magnitude of the specification of this basis material, thus reducing the discharge rate to 0.1% per

30 days, with the result that increasing the thickness of the coating layers provides the flexibility in the design to reduce the leakage and discharge rate further if required.

9. (Amended) An electrical-energy-storage unit as recited in Claim 1 that the relatively low 800° C sintering and hot-isostatic-pressing temperatures allow the use of nickel as the electrode metal rather than expensive platinum, palladium, or palladium-silver alloy.
10. (Amended) An electrical-energy-storage unit as recited in Claim 1 that due to double coating of the composition-modified barium titanate powder, the hot-isostatic-pressing process, the high-density solder-bump packaging, and along with the double-layered array configuration stored 52,220 W·h of electrical energy in a 2003 inches³ container and this energy storage capability was retained over the lower to the upper temperature limits of a commercial product.
11. (Amended) An electrical-energy-storage unit as recited in Claim 1 indicates that the materials used: constituents oxides of barium (Ba), calcium (Ca), titanium (Ti), zirconium (Zr), manganese (Mn), yttrium (Y), neodymium (Nd), in a single-phase solid-solution, and the metals: nickel (Ni), and copper (Cu), are not explosive, corrosive, or hazardous.
12. (Amended) An electrical-energy-storage unit as recited in Claim 1 that can supply electrical energy to electrical vehicles, which include bicycles, tractors, buses, cars, or any device used for transportation or to perform work, and is not explosive, corrosive, or hazardous.

13. (Amended) An electrical-energy-storage unit as recited in Claim 1 that can store electrical energy from electrical-energy-delivery systems and then be used to supply electrical energy to residential, commercial, industrial applications, and the present power grid, and is not explosive, corrosive, or hazardous.
14. (Amended) An electrical-energy-storage unit as recited in Claim 1 that can store electrical energy from electrical-energy-delivery systems and then be transported to a required location and be used as a source of electrical energy and is not explosive, corrosive, or hazardous.
15. (Amended) An electrical-energy-storage unit as recited in claim 1 that can supply electrical energy to portable electronic devices, for example, computers, radios, television sets, cameras, refrigerators, phones, lights, and other such devices.
16. (Amended) An electrical-energy-storage unit as recited in claim 1 that can supply electrical energy to remote devices, for example, microwave repeaters, phones, traffic signals, recreational equipment, lighting systems, camping equipment, farming equipment, and other such devices.

Please add new claim 17:

17. An electrical-energy-storage unit as recited in Claim 1 that due to the double coating of the composition-modified barium titanate powder and the hot-isostatic-pressing process allowed the relative permittivity of 29,480 with an applied voltage of 3500 V to a dielectric thickness of 12.7 microns to be achieved which characteristic is retained over the lower to the upper temperature limits of a commercial product.

Discussion of the art

US Patent No 6,268,054

Stephen A. Costantino, Robert A. Hard, and Sridhur Vanigalla, Inventors

Cabot Corp., Assignee

This patent pertains to metal-oxide coated barium titanate or composition-modified barium titanate powders for the purpose of preventing particle agglomeration. Such agglomeration greatly hinders particle dispersion in the organic binder/solvent mixture required to form an easily screen-printable ink. The use of a single or double coating is described. However, neither the use of an aluminum oxide coating or a calcium magnesium aluminosilicate glass coating is mentioned. The purpose of the metal-oxide coatings described in the US Patent No. 6,260,054 is both to prevent particle agglomeration and to provide ease of high shear mixing of the powder and the binder-solvent mixture, and thereby form a well-dispersed screen-printable ink.

U.S. Patent No. 6,078,494

Peter Hansen, Inventor

U. S. Philips Corporation, Assignee

The composition-modified barium titanate powder is not coated in this patent, unlike the double coating of the powder provided in the patent application 09/833,609. Furthermore, hot isostatic pressing of the ceramic bodies is not used, unlike patent application 09/833,609. Also, as indicated in the Philips Patent on page 5, paragraph 22, "The leakage current increases in a short period of time, i.e., compared to the duration of the measuring process up to then, by several orders of magnitude." The life test is a test

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of the leakage current when 1800 V/mm is applied to the capacitor @ 350° C. The patent application 09/833,609 has a voltage breakdown of 635,000 V/mm at the highest temperature limit of any commercial product and will retain the original specification limits of the product at the 52.2 kW·h over this period of time which will be in the many years range. As can be detected, the importance of the coating of the powders and the hot isostatic pressing of the ceramic bodies utilized in the patent application 09/833,609 produce a different article than the U. S. Patent No. 6,078,494.

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Kita, Hiroyuki et al., Inventor

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The barium titanate powder coated with titanium oxide ○ ○ ○

We assume the titanium oxide to be titanium(IV) oxide, aka titanium dioxide, (TiO₂). The other oxides of titanium are titanium(III) oxide, aka titanium sesquioxide, (Ti₂O₃), which is a semiconductor; and titanium(II) oxide, aka titanium monoxide, (TiO), which is a metallic conductor. TiO₂ is an electrical insulator, but not one of high resistivity. Unfortunately, with the application of a sufficiently high electric field, oxygen loss occurs, and the greater the magnitude of the applied electric field, the higher the rate of oxygen loss, lowering the resistivity as the result. With the electric field applied over time, there is continuing oxygen loss, ultimately leading to semiconductive characteristics, accordingly as follows:

Ti_nO_{2n-x}, where x goes from zero gradually to 0.5n at the ultimate limit, so that voltage breakdown will occur.

This phenomenon does not occur with the coatings of aluminum oxide and calcium magnesium aluminosilicate glass, the former having the highest resistivity of any oxide ceramic and the latter similarly of any silicate glass, used in the patent application 09/833,609.

US Patent No. 6,243,254 B1

Wada et al., Inventors

Murata Mfg. Co., Ltd., Japan, Assignee

This patent describes a vast array of components for composition-modified barium titanate powders suitable for multilayer capacitors with nickel electrodes. The powders are not coated. The glass frit described is for use with the nickel powder to aid in the adhesion of the nickel electrodes to the dielectric layers needed for the lower temperature sintering of the ceramic bodies as compared to the use of platinum, palladium, or palladium-silver alloy electrodes. Hot isostatic pressing would circumvent this need for the use of glass frit with the nickel powder, but it is not mentioned. As indicated in the test results for the seven experiments, the highest relativity permittivity achieved was 3360 and the highest voltage breakdown achieved was 15 kV/mm. The highest relativity permittivity and voltage breakdown achieved as indicated in patent application 09/833,609 are 33,500 and 635 kV/mm. This difference in the test data and the fact that the powders are not double-coated or the use of hot isostatic pressing is not mentioned in the US Patent No. 6,243,354, but are both included in the processing steps in the patent application 09/833,609, indicate that a different article is produced.